

electronic properties of the materials involved and the intensity of the solar radiation incident on the cell.

Conventional solar cell technologies are based largely on single crystal, polycrystalline, or amorphous silicon. The source for single crystal silicon is highly purified and sliced into wafers from single-crystal ingots or is grown as thin crystalline sheets or ribbons. Polycrystalline cells are another alternative which is inherently less efficient than single crystal solar cells, but also cheaper to produce. Gallium arsenide cells are among the most efficient solar cells available today, with many other advantages, however they are also expensive to manufacture.

In all cases of conventional solid-state photovoltaic cells, photon (light) absorption occurs in the semiconductor with both majority and minority charge carriers transported within the semiconductor; thus, both electron and hole transport must be allowed and the band-gap must be sufficiently narrow to capture a large part of the visible spectrum yet wide enough to provide a practical cell voltage. For the solar spectrum the ideal band-gap has been calculated to be approximately

expensive to fabricate. In heterostructures a limited number of acceptable compatible materials are available. Schottky barrier based devices have been proposed in this class that rely, again, on absorption of photons in the semiconductor bulk and use the Schottky barrier for charge separation.

Another class of conventional solar cells are the dye-sensitized photoelectrochemical solar cells as shown in Figure 2. These devices were derived from work on photoelectrochemical electron transfer and are cathode/electrolyte/anode systems in which a photoactive molecule is light activated and oxidized (or reduced) by electron (or hole) transfer to the adjacent semiconductor electrode. The charge transfer agents, which replace the transferred charge in the photoactive molecule, are typically molecules or atoms dissolved in a liquid electrolyte such that the molecules or atoms receive charges from an electrode. Reduction is performed by an electron donor in the liquid electrolyte. This device is limited in its power output by the relative free energies of electrons in the electrolyte and the semiconductor which limit the

The present invention is advantageous over the
aforementioned dye-sensitized Schottky barrier solar
cell structure in that it has the advantage of
potentially greater photovoltages due to the ability to
influence the barrier height by the choice of a high
(for n-type semiconductors) or low (for p-type
semiconductors) work function conductors at the surface,
by the choice of the semiconductor (type and doping
level), and by the surface treatment of the
semiconductor prior to disposition of the conductor to
maximize the barrier height by affecting the interface.
Additional advantages of the present invention include
eliminating the need for a specific reducing agent or a
minority charge carrier transport material, and
providing the ability to choose from among a broad
choice of charge separation layer material to include
both wide band-gap n and p type semiconductors. In
contrast to the prior art, U.S. patent nos. 4,105,470
and 4,190,950 by Skotheim, only two transfers of
electrons to/from conduction bands are required and no
inter-molecular charge transfer is necessarily required.

It is an object of the present invention to: 1) eliminate the need for electrolytes and/or molecular reducing agents and/or minority carrier conductors, 2) allow for a wider choice of the conductor and charge separation layer, and 3) maximize by design of the open circuit photovoltage.

It is another object of the present invention to increase the efficiency of photovoltaic energy generation. More specifically, light absorption can be optimized since a single band-gap is not required for light absorption, and a large number and variety of materials with selectable spectral properties of photoabsorbing molecules or structures can be utilized without the need for compatibility with an electrolyte. Without the overpotential losses of the electrochemical redox reactions (both at the electrodes in the photoelectrochemical cell and by the reducing agent charge transfer), higher efficiencies are also possible. The ultra-thin conductor is used as an efficient ballistic transport channel and to maximize the photovoltage as determined by its effect on the barrier. The interaction between the conductor and charge

embodiment, the photoactive species may be ~~imbedded~~
embedded in the front conductive layer to make a single
composite layer.

5 In fabricating the above-described structure, the
photosensitizer layer, the front and back conducting
layers, and the charge separation layer can be deposited
by vapor deposition, electrochemical deposition,
deposition from solution or colloidal suspension, or be
produced by evaporative, extrusion, or other
10 conventional polymer manufacturing techniques. With
specific regard to the charge separation layer 39, it
may be created with high surface area using organic
template molecules, or it can be nano-, meso-, or macro-
porous to increase the surface area. The conductor and
15 photoactive layers would then follow the contoured
surface (see Figure 16).

In a specific fabrication example comprising the
preferred embodiment of the invention, a charge
separation layer 39 of titanium dioxide is deposited
20 onto titanium foil (the ohmic back contact 30). The
charge separation layer 39 has a thickness ranging
between 100 nm and 500 nm and is deposited by electron

degenerate levels with less hindrance due to quantum state restrictions. A specific example would be the deposition of CdSe or CdS nanoparticles (~5 nm in dimension) on the conductor surface. These semiconductor particles have been shown to have efficient capture and efficient transfer to semiconductors. Interposing the conductor ballistic transport will still allow charge transfer; however, the particle can now be supplied with compensation charge directly from the conductor.

In accordance with another alternative embodiment of the present invention as shown in Figure 5, the electrons 36 of the photosensitizer layer 10 do not ballistically transport through the front conducting layer 31. Rather, as the excited electrons 36 relax back to lower energy states, energy released from electrons 36 excites electrons 50 that reside in the front conducting layer 31. The excited electrons 50 may thereafter rise above the conduction band energy ~~band~~ 38 and flow towards the back conducting layer 30.

In yet another alternative embodiment as shown in Figure 6, the front conducting layer 31 is selected from

surface. The dimensions of the quantum well and the properties of the material are chosen to optimally inject the charges.

Figure 14 shows an embodiment where absorption occurs in a structure or molecule partially isolated from the conductor to reduce coupling for optimal charge transfer. Examples include metal oxides, silicon dioxide, titanium dioxide, aluminum dioxide, organic chains and self-assembled monolayers deposited on the surface prior to the photoabsorber. For example, a thin layer of titanium dioxide (~1-5 nm) is deposited on the conductor (Au). The photoactive merbromin is applied and forms a covalent linkage through its active carboxylate moiety to the titanium (C-O-Ti).

As previously discussed, in fabricating a device in accordance with the preferred embodiment, a charge separation layer 39 of titanium dioxide is deposited onto titanium foil (the ohmic back contact 30). The charge separation layer 39 has a thickness ranging between 100 nm and 500 nm and is deposited by electron beam evaporation and/or by electroanodization of the titanium metal. Gold is then deposited to the composite

layer to a thickness of 10 nm to form the ultra-thin conductor. The resulting current voltage curves of the Schottky contact are shown in Figure 18. Also shown in Figure 18 for comparison are devices using nickel instead of gold as the ultra-thin conducting layer 31. An approximately 0.8 eV barrier results.

In accordance with the alternative embodiment of Figure 14, 2 nm of titanium dioxide is deposited onto the above-mentioned ~~metal~~ front conducting layer ~~conductor~~ 31 as a partial isolation layer. Photoactive merbromin is then applied and bonded covalently through its active carboxylate moiety to the titanium (C-O-Ti) to complete the active device.

Figure 15 shows an alternative embodiment comprising a polymer based device wherein a ballistic hole is injected into an ultra-thin hole carrier. Polymer A in Figure 15, (e.g., poly(p-phenylene vinylene), (PPV) with its highest occupied molecular orbital (HOMO) level lower in energy than the HOMO of a second polymer (B in Figure 15) hole conductor layered behind it. The PPV provides a barrier to reverse hole transport serving the same role as the Schottky barrier.